IWT-TETRA: ZON-WARM

Solar Thermal and Heat Pump Systems

&

Domestic Hot Water production

Jan Verheyen

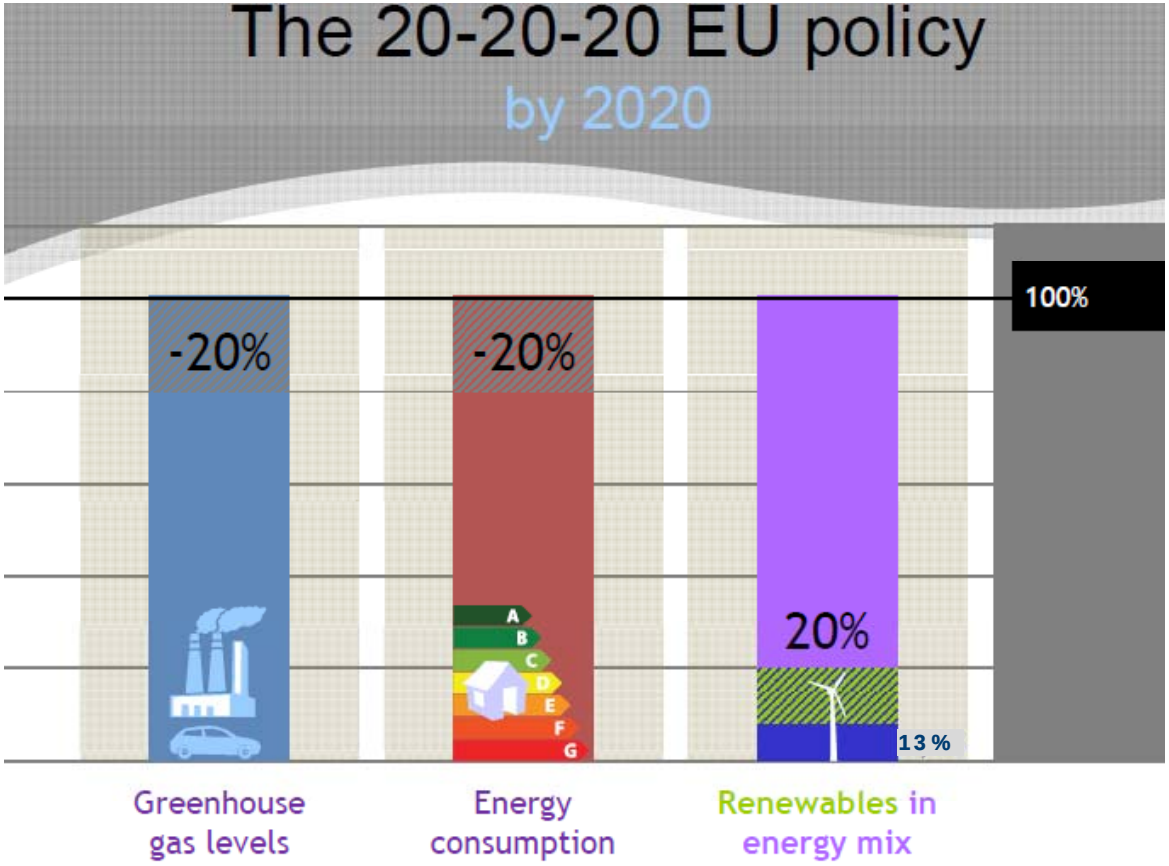
K.H.Kempen en Lessius bundelen de krachten en worden *more*.

CONTENT

- Introduction
  - Context & Project Zon-Warm
  - Role of Domestic Hot Water (DHW) in Solar Thermal and Heat Pump (SHP) systems
- Subject
  - Household size
  - $T_{set,\ DHWtank}$
  - Penalty factor electricityDHW BU heater

  → Energy Performance
- Approach
  - System simulations
  - DHW profiles
  - System configurations & sizing
- Results
- Conclusions

CONTEXT



40% energy use
36% CO_2 emission
= building related

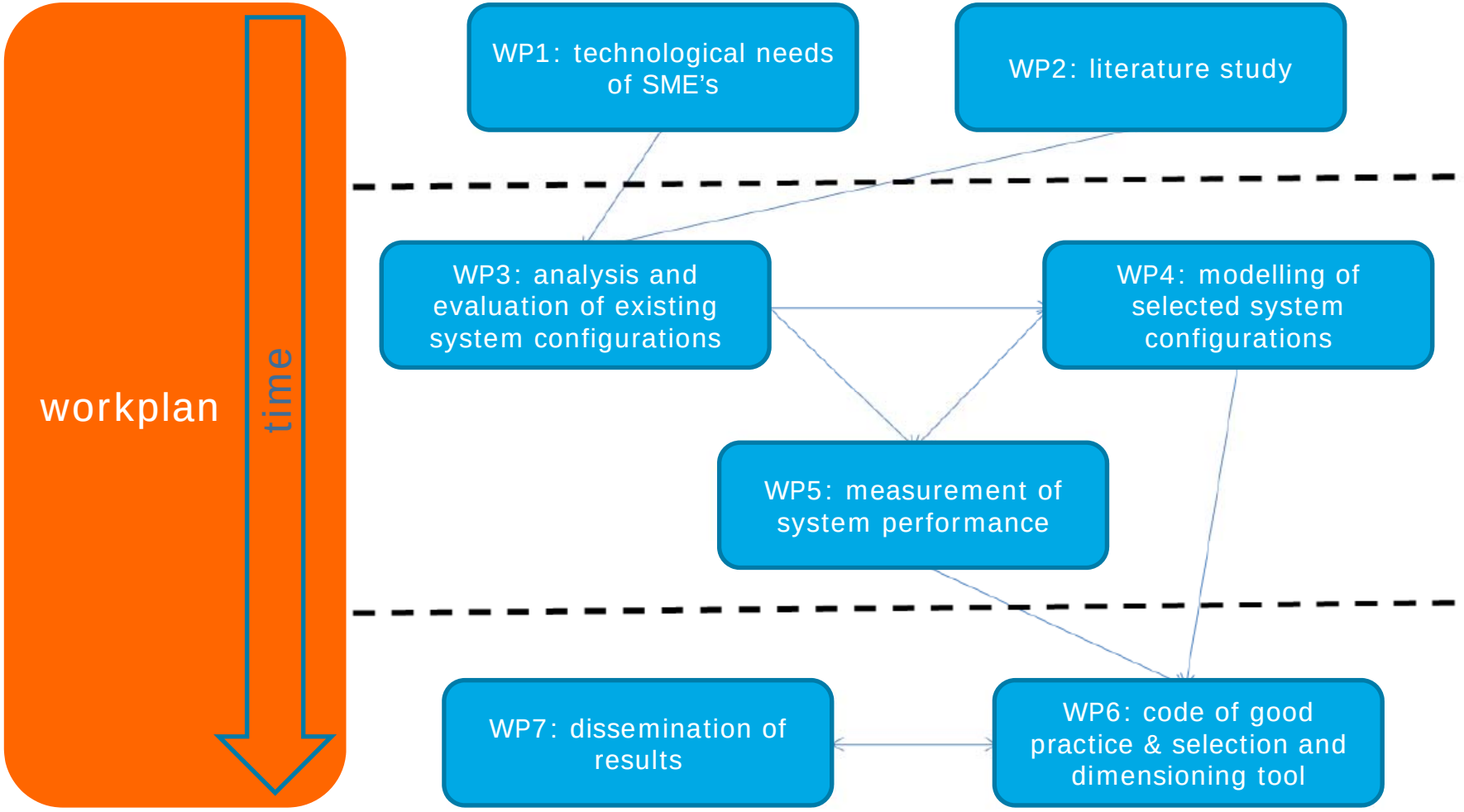
IWT-TETRA PROJECT ZON-WARM

- Subject:
  - Coupled Solar Thermal & Heat Pump Systems residential heating & domestic hot water
- Objectives:
  - Market penetration: relief of barriers
    → augmenting quality by optimization
  - TETRA technology transfer
- Team
  - Scientific partners (3)
  - Non-profit or sectorial (5)
  - Governamental organisations (1)
  - SME's (19)
- Project coördination: THELES, Thomas More
- Funding: IWT
- Participation in IEA-SHC task 44 / annex 38

THOMAS MORE
K.H.Kempen and Lessius are joining up to become more.

iwt

IWT-TETRA PROJECT ZON-WARM



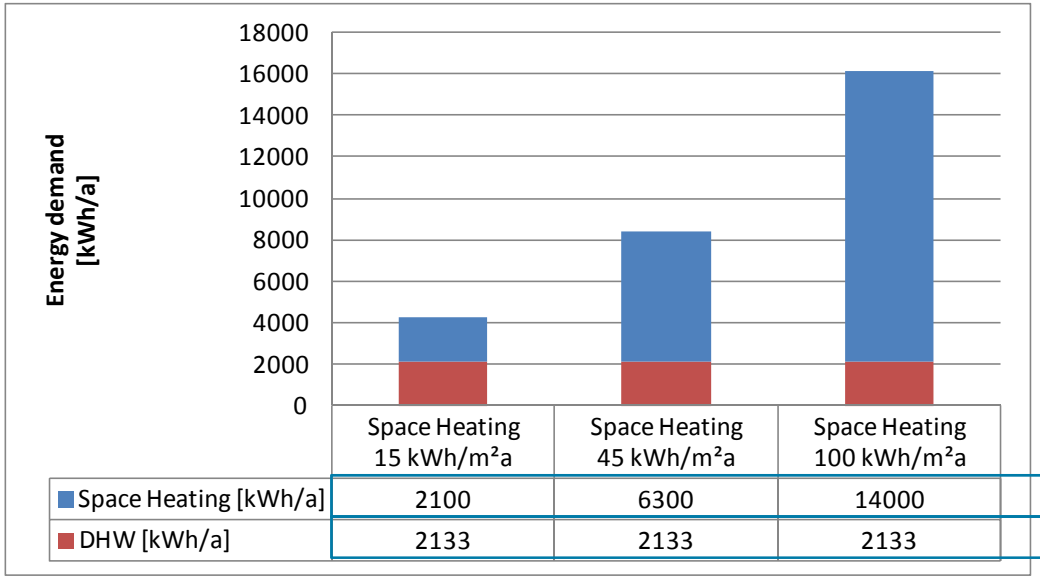
IWT-TETRA PROJECT: ZON-WARM

Web: http://zon-warm.lessius.eu/

SUBJECT: CONTEXT

SOLAR THERMAL AND HEAT PUMP SYSTEMS & DOMESTIC HOT WATER PRODUCTION

- Role of DHW in energy demand and system design:



	Space Heating 15 kWh/m²a	Space Heating 45 kWh/m²a	Space Heating 100 kWh/m²a
Space Heating [kWh/a]	2100	6300	14000
DHW [kWh/a]	2133	2133	2133

$A_{useable} = 140 m^2$

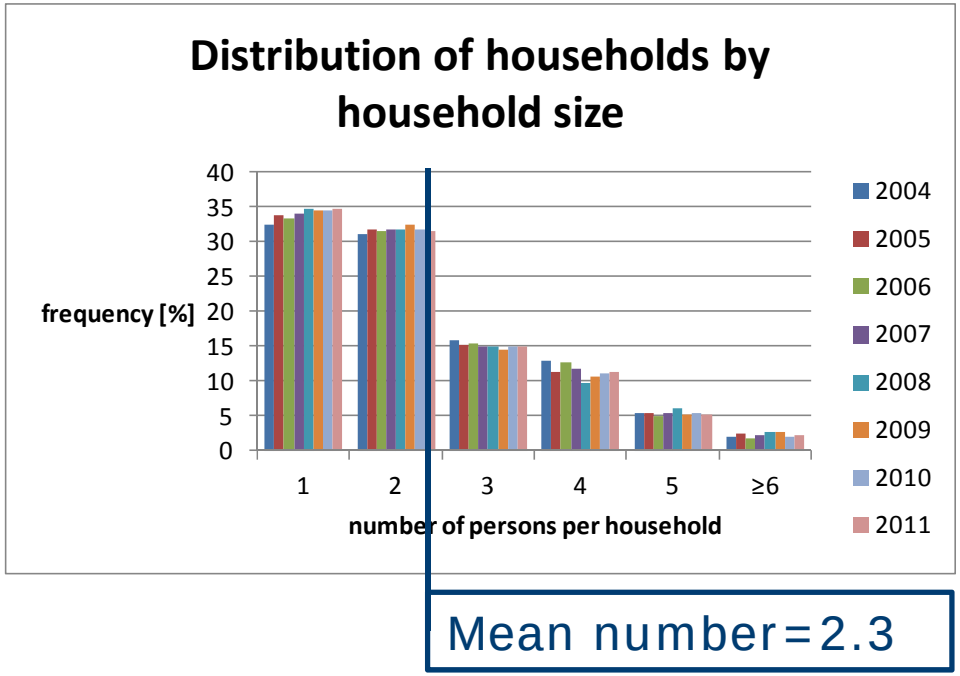
T44 [Haller et al.; 2013]

» SFH015: further savings in SH demand → increasing effort

» SFH015: optimization → focus on DHW

SUBJECT

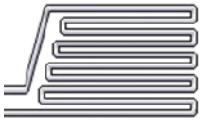
- Influence of
  - household size on system performance
  - $T_{set\ DHW\ tank}$
- Influence of
  - penalty factor (DHW backup heater el. cons.)



APPROACH: SYSTEM SIMULATIONS

- Software: Polysun v6.1 [Vela Solaris; 2013]
- Boundary conditions: fixed
  - Climate: Sint Katelijne Waver (lat. 51.068°, long. 4.501°, el. 4m)
  - Building: heating load:
    - SFH015 (~Passive house, Strassbourg) [Dott et al.; 2012]

      → specific heating demand = 21.1 kWh/(m².a) [B]
    - Useable floor area: 140m²
    - Floor heating T_{supply}/T_{return} = 35°C/30°C
    - Design heat load = 1673W [B]

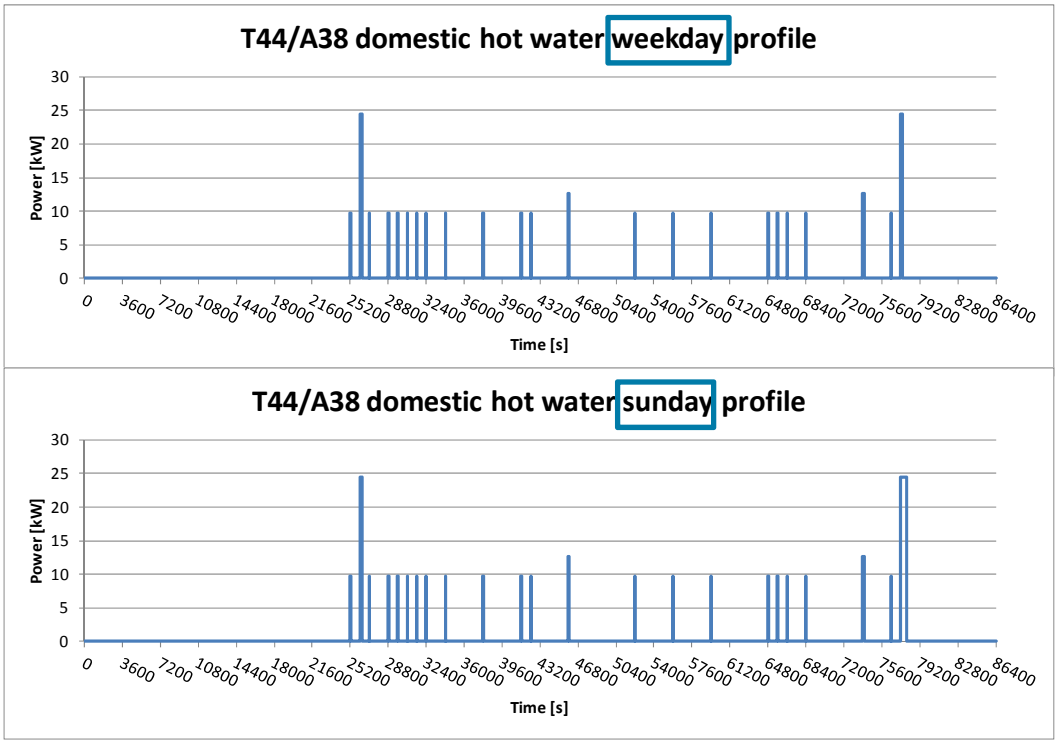


DHW PROFILES

Legend:
S=Small; Sh=Shower; FC=Floor cleaning;
DW= Dish washing; HC=Household cleaning;
Ba=Bath tub

[Haller et al.; 2013]

- T44 DHW reference profile



Weekdays:

Nr.	start time (h:min)	Energy $Q_{dhw,std}$ (kWh)	Type	Flow Rate (L/h)	Min. Temp. $\theta_{dhw,set}$ (°C)
1	07:00	0.100	S	240	45
2	07:15	1.315	Sh	600	45
3	07:30	0.100	S	240	45
4	08:00	0.100	S	240	45
5	08:15	0.100	S	240	45
6	08:30	0.100	S	240	45
7	08:45	0.100	S	240	45
8	09:00	0.100	S	240	45
9	09:30	0.100	S	240	45
10	10:30	0.100	FC	240	45
11	11:30	0.100	S	240	45
12	11:45	0.100	S	240	45
13	12:45	0.300	DW	240	55
14	14:30	0.100	S	240	45
15	15:30	0.100	S	240	45
16	16:30	0.100	S	240	45
17	18:00	0.100	S	240	45
18	18:15	0.100	HC	240	45
19	18:30	0.100	HC	240	45
20	19:00	0.100	S	240	45
21	20:30	0.700	DW	240	55
22	21:15	0.100	S	240	45
23	21:30	1.315	Sh	600	45
Total		5.530			

Sunday: bath tub replaces shower:

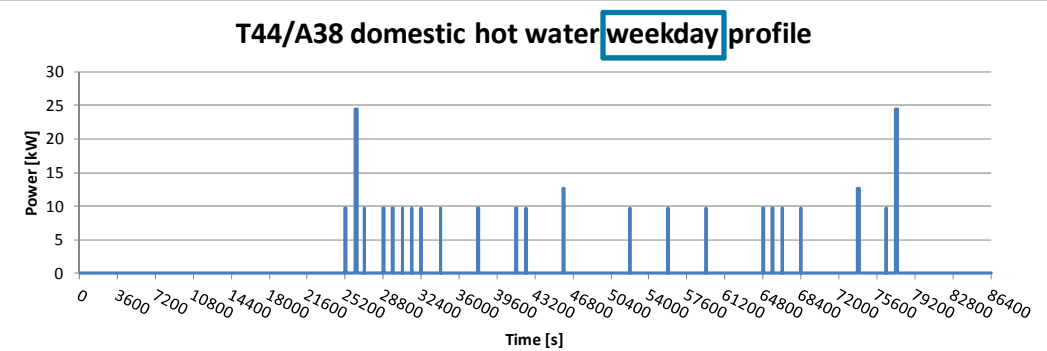
23	21:30	3.520	Ba	600	45

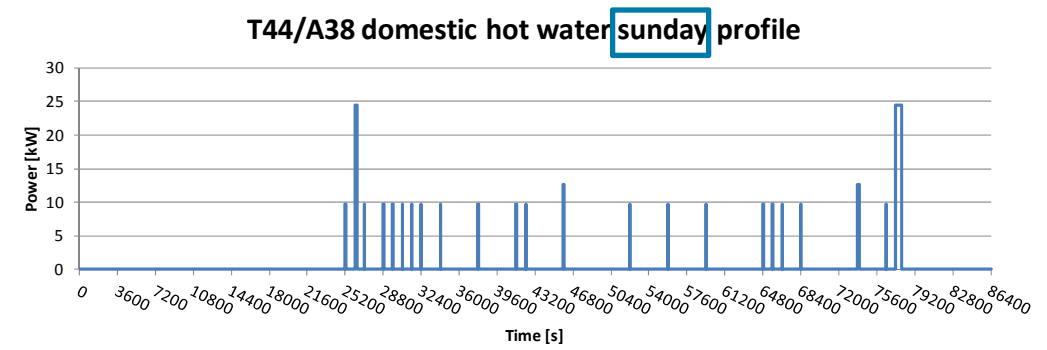
DHW PROFILES

Legend:
S=Small; Sh=Shower; FC=Floor cleaning;
DW= Dish washing; HC=Household cleaning;
Ba=Bath tub

[Haller et al.; 2013]

- T44 DHW reference profile





82.9% → 45°C
17.1% → 55°C

=5.845 kWh/day

~140 l/day at 45°C (T_{cw}=10°C)

DHW PROFILES

DHW profile name	$T_{DHW,draw\text{-}off}$ [°C]*	daily amount [l/d]	$E_{avg,day}$ [kWh/d]**	amplitude summer/winter	rate of E_T44***	V [m³/a] (excl. BU heater)
SHP_DHW_40_100	40	*153.33*	5.845	-20%/+20%	100%	50.409
SHP_DHW_45_100	45	*140.00*	5.845	-20%/+20%	100%	50.409
SHP_DHW_50_100	50	*126.66*	5.845	-20%/+20%	100%	45.016
SHP_DHW_55_100	55	113.33	5.845	-20%/+20%	100%	40.814
SHP_DHW_60_100	60	100.00	5.845	-20%/+20%	100%	36.754
SHP_DHW_45_43	45	60.87	2.541	-20%/+20%	43%	21.676
SHP_DHW_55_43	55	60.87	2.541	-20%/+20%	43%	17.55
SHP_DHW_45_87	45	121.74	5.083	-20%/+20%	87%	43.856
SHP_DHW_55_87	55	121.74	5.083	-20%/+20%	87%	35.508
SHP_DHW_45_130	45	182.61	7.624	-20%/+20%	130%	65.532
SHP_DHW_55_130	55	182.61	7.624	-20%/+20%	130%	53.058
SHP_DHW_45_174	45	243.48	10.165	-20%/+20%	174%	87.712
SHP_DHW_55_174	55	243.48	10.165	-20%/+20%	174%	71.016
SHP_DHW_45_217	45	304.35	12.707	-20%/+20%	217%	109.388
SHP_DHW_55_217	55	304.35	12.707	-20%/+20%	217%	88.566

Energy associated with BU heater is considered outside Polysun

DHW PROFILES

DHW profile name	$T_{DHW,draw-off}$ [°C]*	daily amount [l/d]	$E_{avg,day}$ [kWh/d]**	amplitude summer/winter	rate of E_T44***	V [m³/a] (excl. BU heater)
SHP_DHW_40_100	40	*153.33*	5.845	Variation over the year Sine-curve amplitude: 20%	100%	50.409
SHP_DHW_45_100	45	*140.00*	5.845		100%	50.409
SHP_DHW_50_100	50	*126.66*	5.845		100%	45.016
SHP_DHW_55_100	55	113.33	5.845		100%	40.814
SHP_DHW_60_100	60	100.00	5.845		100%	36.754
SHP_DHW_45_43	45	60.87	2.541		43%	21.676
SHP_DHW_55_43	55	60.87	2.541		43%	17.55
SHP_DHW_45_87	45	121.74	5.083		87%	43.856
SHP_DHW_55_87	55	121.74	5.083		87%	35.508
SHP_DHW_45_130	45	182.61	7.624		130%	65.532
SHP_DHW_55_130	55	182.61	7.624		130%	53.058
SHP_DHW_45_174	45	243.48	10.165		174%	87.712
SHP_DHW_55_174	55	243.48	10.165		174%	71.016
SHP_DHW_45_217	45	304.35	12.707		217%	109.388
SHP_DHW_55_217	55	304.35	12.707		217%	88.566

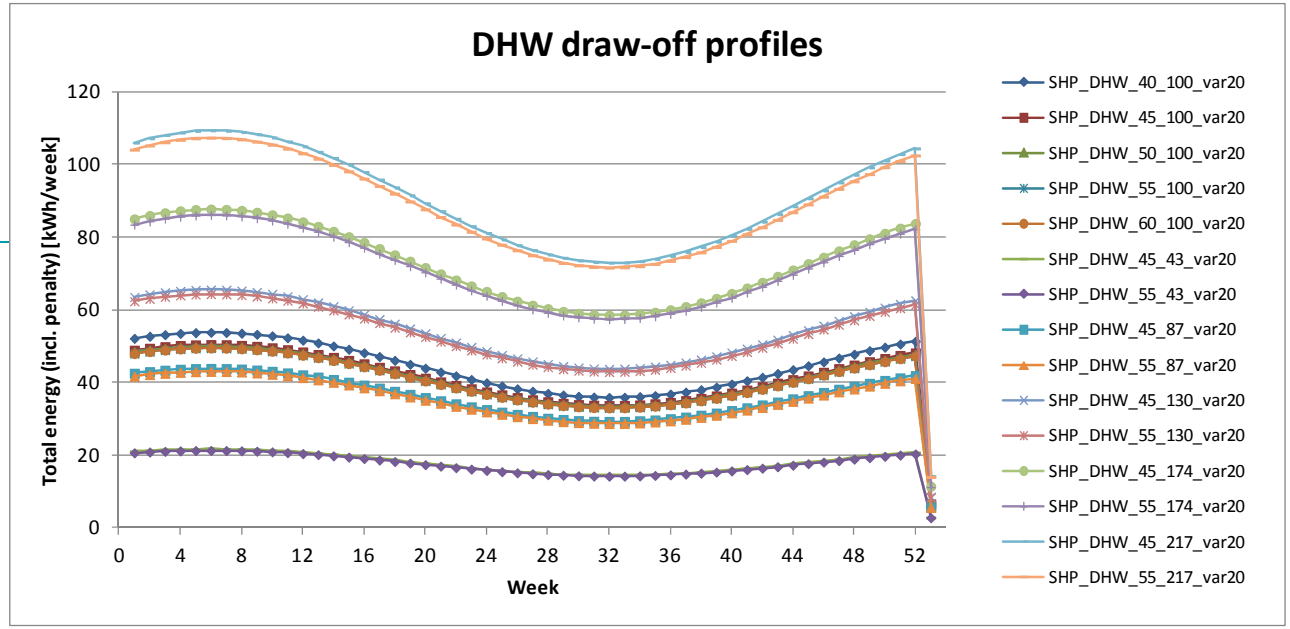
Influence of temperature

Influence of household size

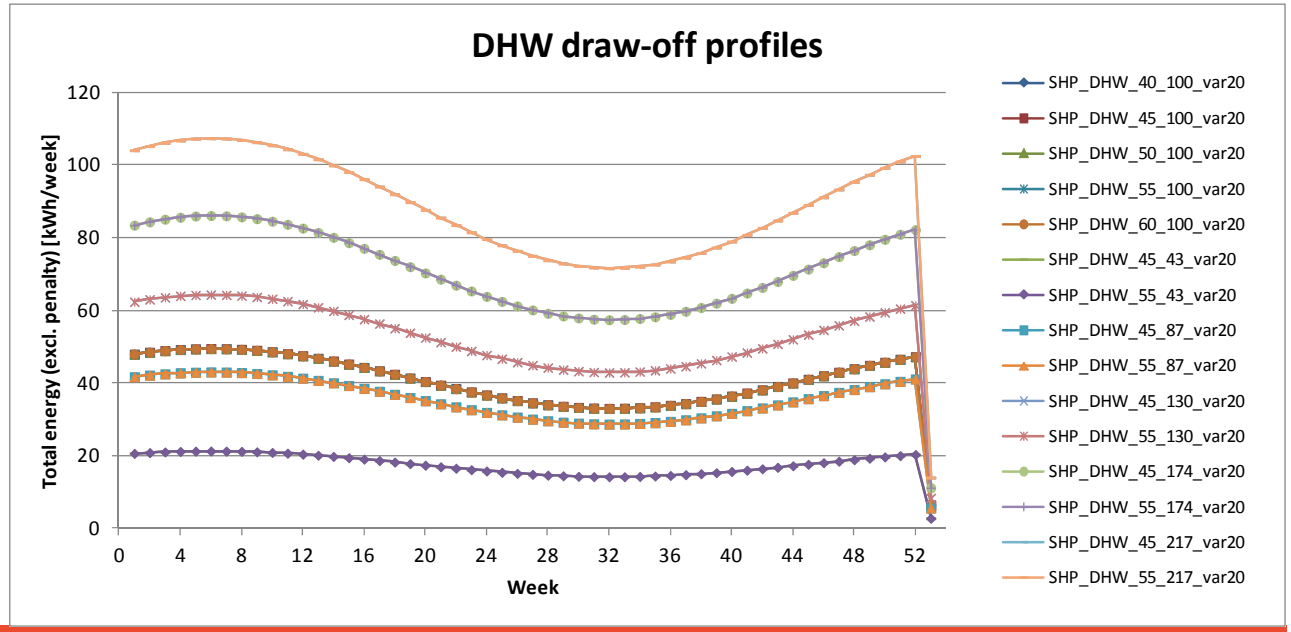
Energy associated with BU heater is considered outside Polysun

DHW PROFILES

- Penalty=1.5



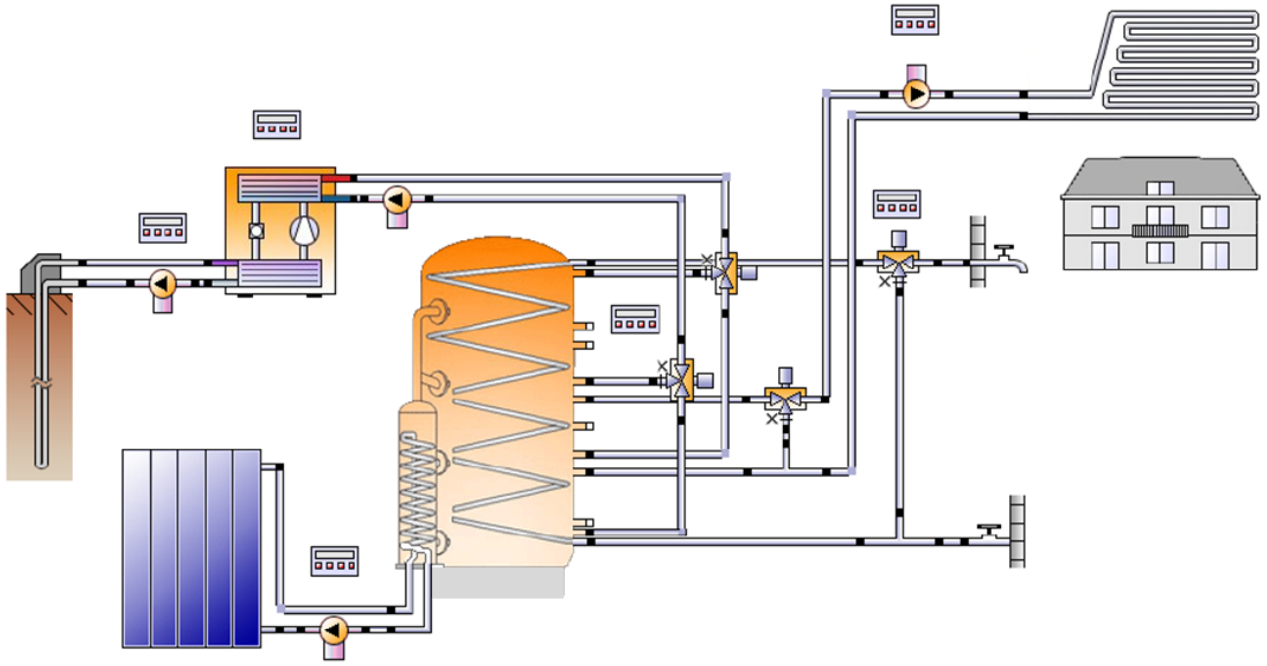
- Penalty=1 (no penalty)



SYSTEM CONFIGURATIONS

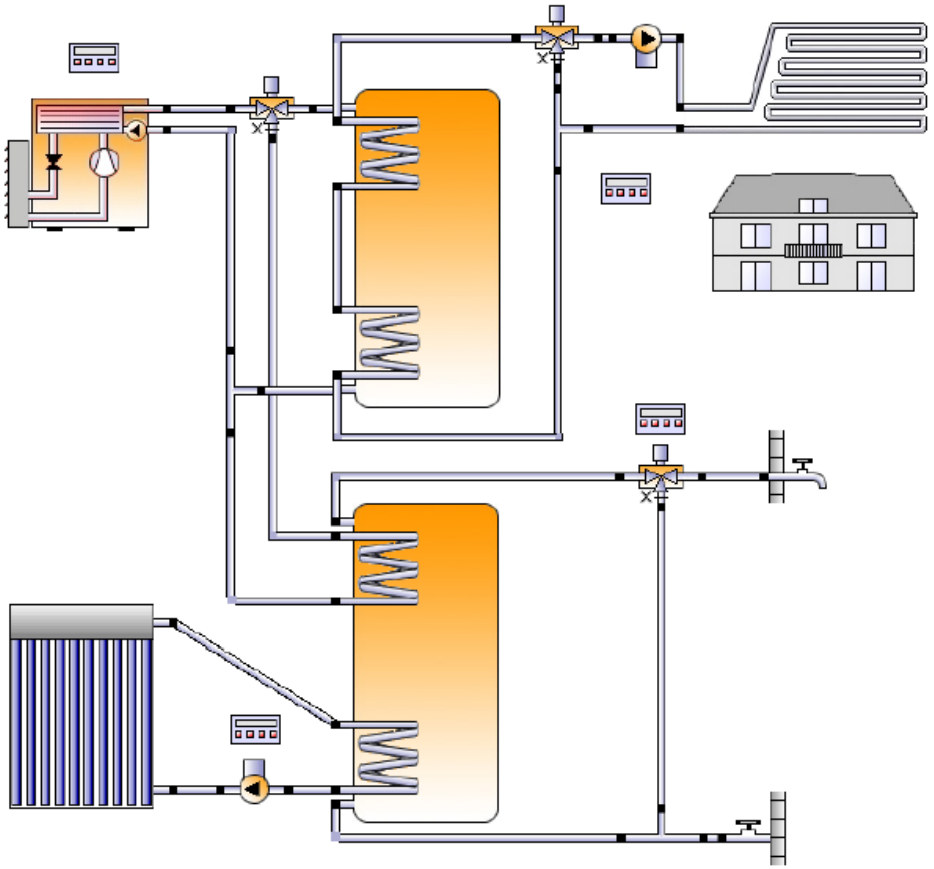
- System 1
  - Stratified tank
    - 512l
    - 10cm PUR
  - HP:
    - B/W HP: R407C
    - 5.6kW
    - COP 4.3
    - GSHX:

      single 32mm U
      86m depth
  - SC
    - flat plate:
    - $A_{aperture}$: 8.6m²
  - On/off pumps



SYSTEM CONFIGURATIONS

- System 2
  - DHW tank:
    - 224l
    - 10cm PUR
  - SH tank:
    - 288l
    - 10cm PUR
  - HP:
    - A/W HP: R410A
    - 5.5kW
    - COP 3.4
    - Internal pump on return line of SH
  - SC:
    - Vacuüm tube (heat pipes)
    - $A_{aperture}$: 3.2m²
  - On/off pumps



SYSTEM SIZING

*[McCorry et al.; 2011] [CEN; 2007]

- Heat Pump:
  Assumption: no heat delivered by SC
  - DHW: (3.8kW)
    - Max. DHW energy for 1 day (winter, sunday, $T_{cw}=T_{a,24h\ avg.\ year}$)
    - 24h tank losses
    - 3 running hours of HP (availability time of HP for DHW=3:00-6:00)
  - SH: Design heat load of building (1.7kW)

    (Availability time of HP for SH=allways)
- GSHX: BHE: $depth_{BHE}=P_{HP}$. (COP-1)/COP/(50W/m*)
- Tank DHW:
  - Max DHW volume for 1 day (winter, sunday)
- Tank SH: (288l)
  - Energy of design heat load during 1 hour
    (1h buffering of design heat load)

- SC: area so that for 1 or 2 months: SF=100%

$P_{HP}=5.5kW$

$depth_{BHE}=86m$

$V_{tank\ sys2,\ DHW}=224l$

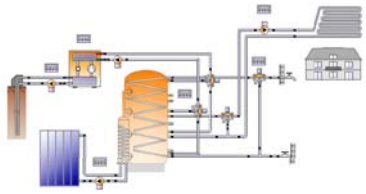
$V_{tank\ sys2,\ SH}=288l$ ✚ $V_{tank\ sys1}=512l$

$A_{aperture,\ Sys1}=8.6m^2$

$A_{aperture,\ Sys2}=3.2m^2$

RESULTS

1



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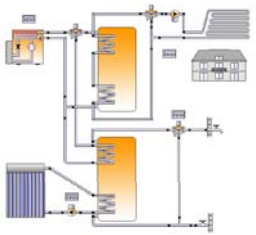
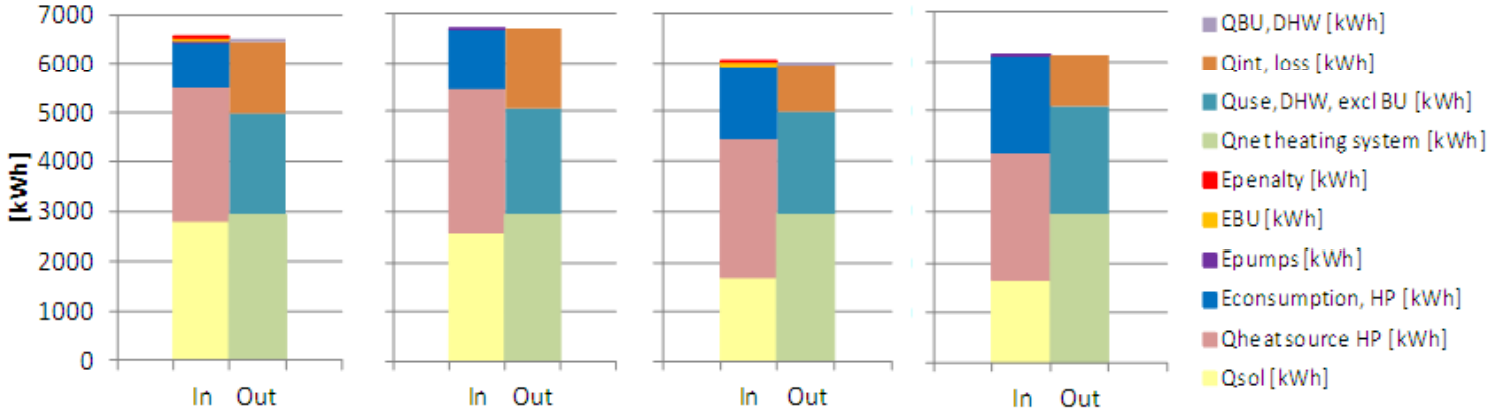
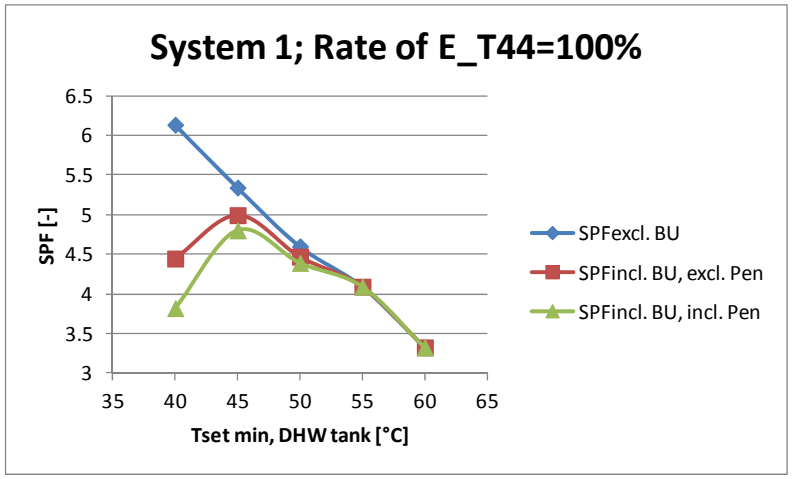


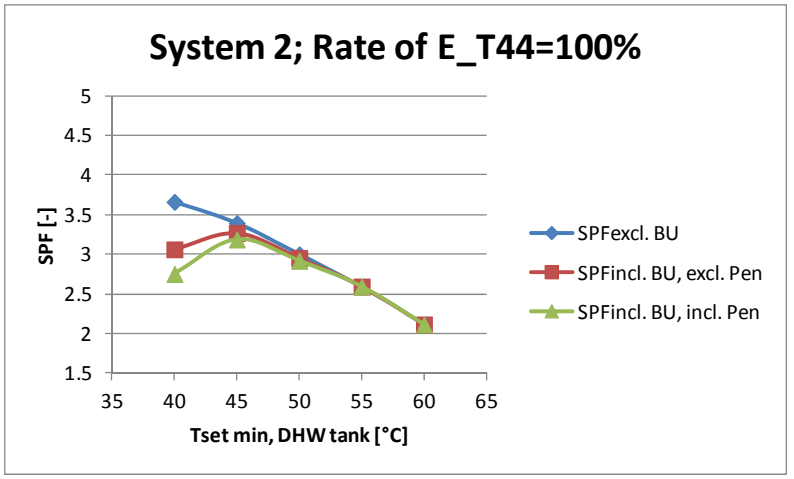
	System 1		System 2	
	SHP_DHW_45_100	SHP_DHW_55_100	SHP_DHW_45_100	SHP_DHW_55_100
$SPF_{excl.\ BU}$ [-]	5.34	4.09	3.39	2.59
$SPF_{incl.\ BU,\ excl.\ pen}$ [-]	4.99	4.09	3.27	2.59
$SPF_{incl.\ BU,\ incl.\ pen}$ [-]	4.80	4.09	3.19	2.59
$SF_{excl.\ BU}$ [%]	43.3	38.5	28.6	27.0
$SF_{incl.\ BU,\ excl.\ pen}$ [%]	42.8	38.5	28.2	27.0
$SF_{incl.\ BU,\ incl.\ pen}$ [%]	42.5	38.5	28.0	27.0
SPF_{HP}	4.01	3.40	2.90	2.29
SPF_{SC}	1032	1030	260	284
S_{HP} [%]	56.7	61.5	71.4	73.0
S_{SC} [%]	43.3	38.5	28.6	27.0
$A_{SC,aperture}$ [m^2]	8.6	8.6	3.2	3.2



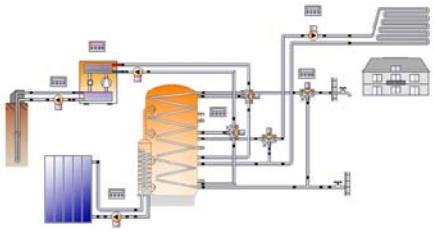
RESULTS

- Comparison of $T_{set,DHWtank}$ (T44 DHW profile)





1



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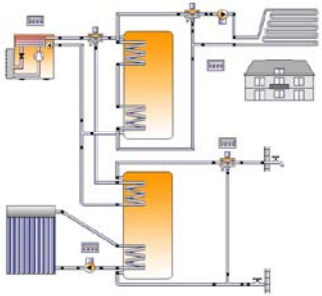
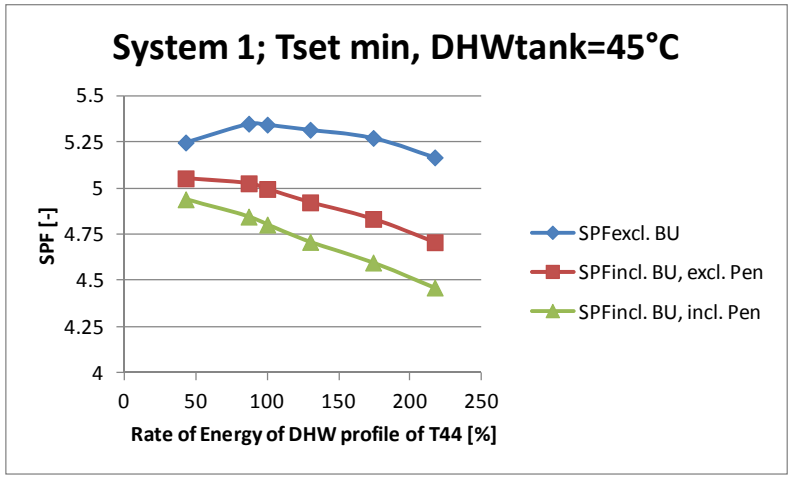
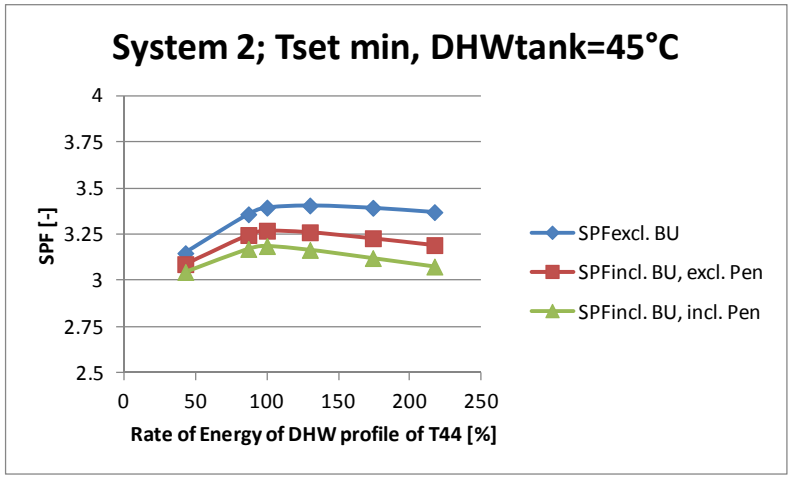


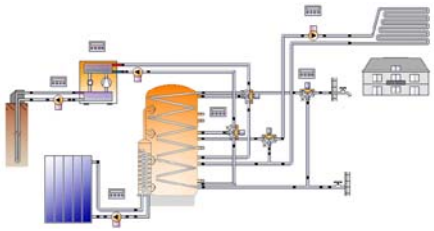
RESULTS

- Comparison of household size ($T_{set,DHWtank}$ =45°C)





1



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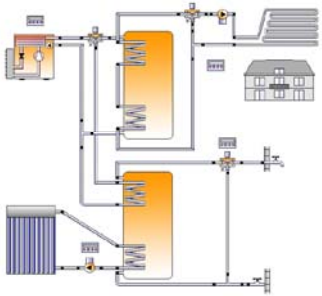
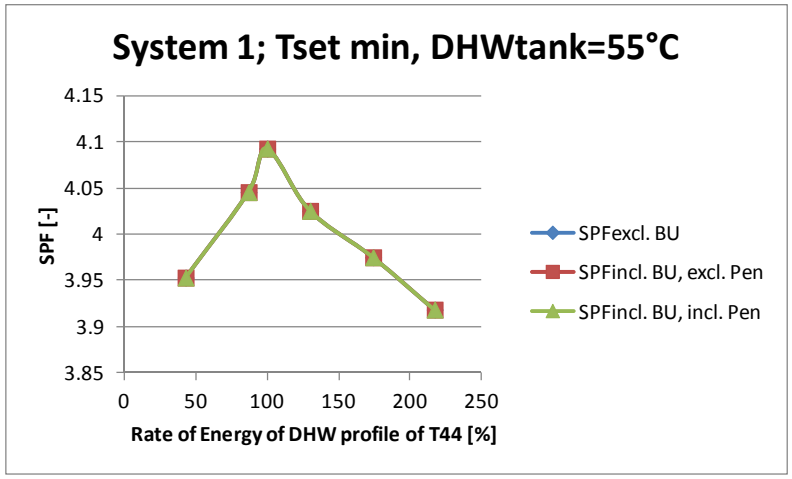
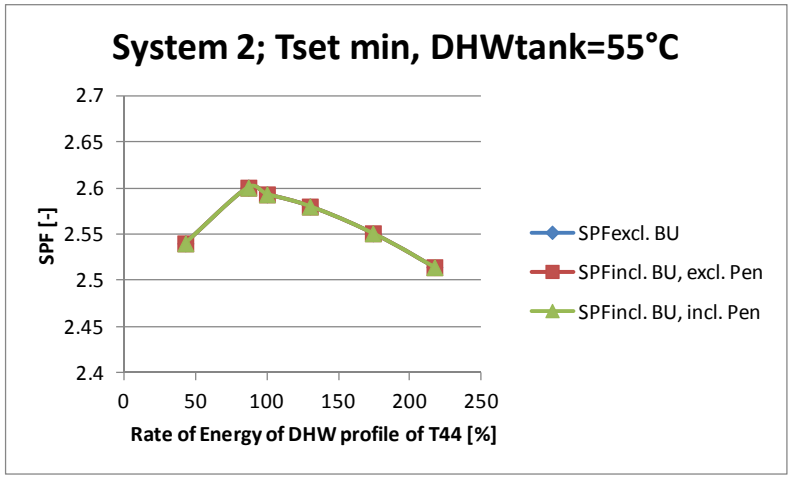


RESULTS

- Comparison of household size ($T_{set,DHWtank}$ =55°C)





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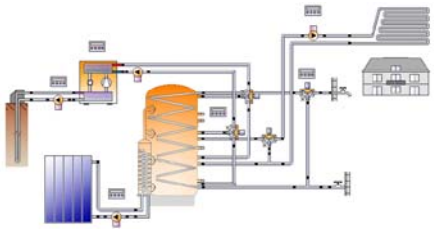

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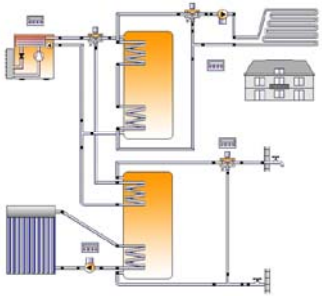
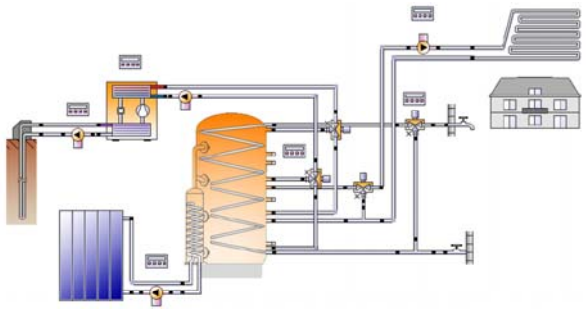


CONCLUSIONS

1



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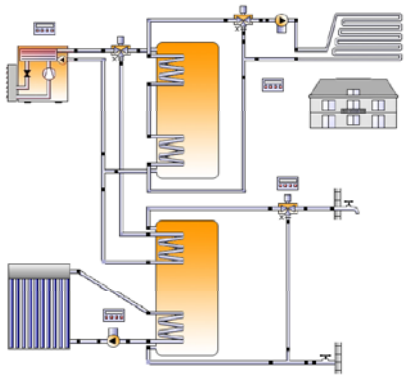

- Regardless of performance indicator used:
  - Performance System 1 **>>** Performance System 2 (note $\Delta A_{SC,aperture}$!!)
  - Δhousehold size →ΔSystem Performance (less pronounced for system 2)
- Properly sized SHP systems → lower SPF can be expected for other DHW profiles than the one it was designed for

  (e.g. change in household size)
- Best performance @ $T_{set,DHWtank}$=45°C (Both systems with T44 DHW profile)
- Penalty factor (1.5) for electricity consumption of DHW BU heater may be decisive in disfavor of SHP systems with BU heater when comparing performance to other systems.

COMBINED SOLAR THERMAL AND HEAT PUMPS SYSTEMS & DHW PRODUCTION

Thank you for your attention!

Web: http://zon-warm.lessius.eu/

Contact: jan.verheyen@thomasmore.be

REFERENCES

- IWT-TETRA project ZonWarm: Zongekoppelde warmtepompsystemen ; http://zon-warm.lessius.eu/
- IEA-SHC task 44 / annex 38; http://task44.iea-shc.org/
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